Experiments in Architectural Form Generation Using Cellular Automata

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Abstract. These experiments are based on previous work in developing cellular automata in three dimensions and to suggest architectural forms. Current research is extended by including explicit architectural considerations, such as, individual space units, supporting structure, floor plates, and the development of an envelope. A basic spatial shape is demonstrated in both linear and curved configurations. Also included is a discussion to not only explicitly use mathematically based concepts for form generation but more importantly their interpretation into architectural forms, as well as, the concept of considering architectural elements from the very start of the generative process.

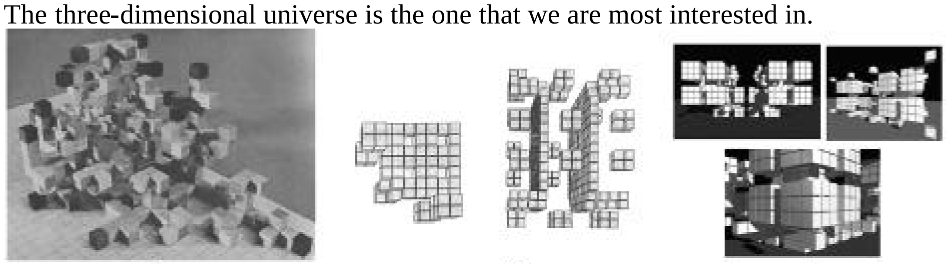
Keywords. Cellular automata, form generation.

Introduction

Cellular automata is the computational method which can simulate the process of growth by describing a complex system by simple individuals following simple rules. This concept of simulating growth was introduced by John von Neumann (1951) and further developed by Ulam (1962) in the area of simulating multi-state machines. The concept gained great popularity when Martin Gardner (1970) described John Conway's "Life", a game that generated two-dimensional patterns. Stephen Wolfram (1984) began researching the concept to represent physical phenomena and has now reintroduced the discussion in "A New Kind of Science" (2002).

The interest in architecture is the ability of cellular automata to generate patterns, from organized patterns we might be able to suggest architectural forms. Cellular automata, viewed as a mathematical approach, differs from a traditional deterministic methods in that current results are the basis for the next set of results. This continues in an iterative fashion until some state is achieved. Fractals and strange attractors are also created in a similar manner. Many digital methods in architecture are parametrically driven, Krawczyk (1997, 2000), an initial set of parameters is used to generate one result. If an alternative is desired, the parameters need to be modified and the generation is repeated anew.

The universe for cellular automata has evolved over a number of dimensions, Wolfram, one-dimensional, Conway, two-dimensional, and Ulam, three-dimensional. The three-dimensional universe is the one that we are most interested in.



a. b. c.

Figure 1. Three-dimensional cellular automata

An early example of three-dimensional pattern development is the block model created by Schrandt and Ulam (1970), Figure 1a. Investigating repeating patterns as Conway found in two-dimensions is Bays (1987), Figure 1b. and finally an inspirational architectural application by Coates (1996), Figure 1c. The striking similarity in these is the explicit representation of the cellular automata, even though each had taken a different approach and had a different application as a investigative goal.

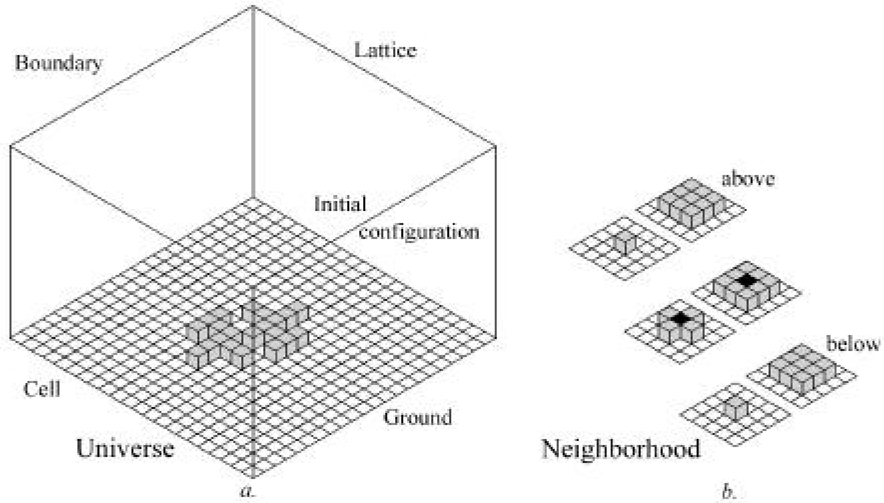


Figure 2. Basic cellular automata terminology

The basics

The three-dimensional universe, Figure 2a., of cellular automata consists of a unlimited lattice of cells. Each cell has a specific state, occupied or empty, represented by a marker recording its location. The transitional process begins with an initial state of occupied cells and progresses by a set of rules to each succeeding generation. The rules determine who survives, dies, or is born in the next generation. The rules use a cell's neighborhood to determine its future. The neighborhood can be specified in a number of ways, Figure 2b. displays two common methods of determining which adjacent cells to consider. Conway's rule: check each occupied cells' neighborhood, survival occurs if there are two or three neighbors and death occurs if any other number of cells are adjacent. Birth occurs in an empty cell if it is adjacent to only three neighbors. As each generation evolves, one of four cases can occur over some period of time. Either the cells find a stable form and appear not to change; or they become what is called a "blinker" and alternate between two stable states; or all or a cluster of the cells become a "glider", a group of cells that begins to transverse the universe forever, and finally all the cells die, extinction. A variety of rules have been proposed, with Conway's being the traditional starting point.

Architectural interpretation

The pure mathematical translation of a cellular automata into architectural form includes a number issues that do not consider built reality. For example, Figure 3 displays an initial configuration, 3a., and its raw results at the 8^{th} generation, 3b. The interpretation or translation to a possible built form can be dealt with after the form has evolved or it can be considered from the very beginning. Deciding to follow the a combination of both approaches, a boundary is placed on the lattice to represent a site, along with a ground, and the orientation that growth is vertical and to the sides, but not below. The cells are stacked over each other to create a vertical connection without a vertical displacement between layers of cells.

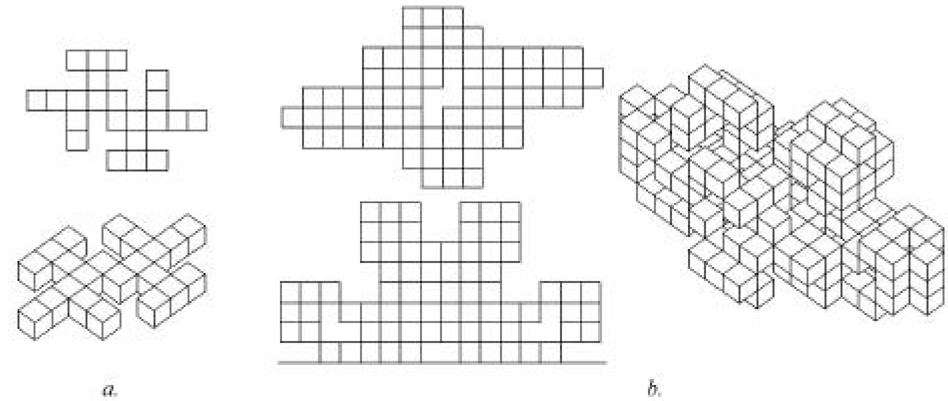


Figure 3. Sample generation

An initial review of the results highlighted a number of other issues; some cells had no vertical support and some cells were not connected horizontally to others. Also the cells do not have an architectural scale or suggest any interior space. Figure 4 displays a typical layer of cells and a series of interpretations that were made to address these issues, all of which are of interest architecturally. The centroid of each cell becomes the basis for this further development. In 4a. the cell remains a square unit but is scaled so to overlap its neighbors. Next, 4b., the cells are merged to form larger units of space. Further, this envelope can be interpreted as a curve or a spline, as in 4c. and 4d. The entire character of the exterior edge of the initial cells changes by these interpretations, as well as, addressing the interior horizontal connections between spaces.

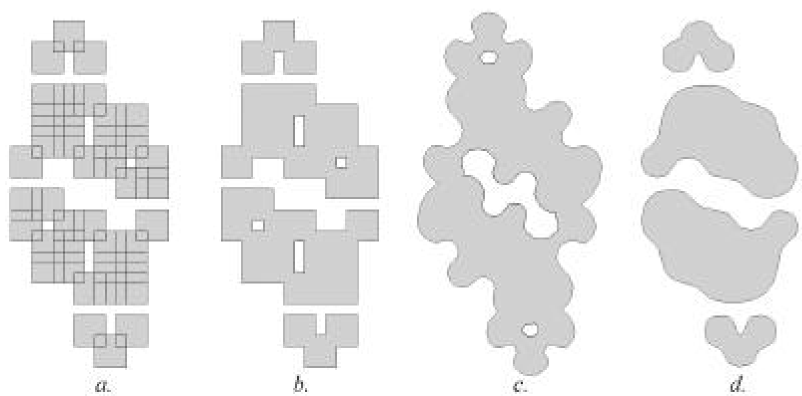


Figure 4. Cell interpretation

When seen in totally as in Figure 5. the following issues are also addressed. Displayed in 5a. is the raw cell configuration with supports represented as a mass model and with the cells represented as spatial modules of three floors each. Individual floor plates are included and each set of merged cells has a glass enclosure. In 5b. and 5c. are the curve and spline versions. One of the interesting aspects on this particular interpretation is the interior spaces created by the merging of the cells. A number of other merge schemes were investigated to further develop this concept. To articulate the edges of each layer of cells, a variety of spatial units were also investigated.

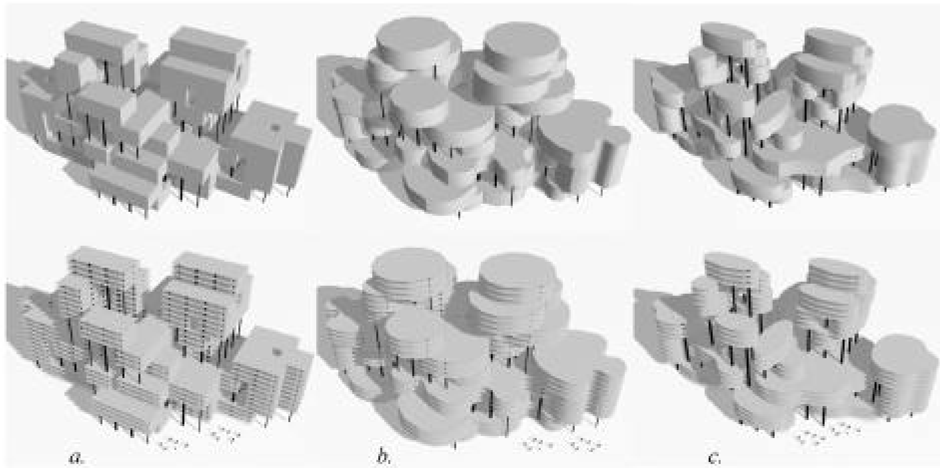


Figure 5. Architectural form

Observations

Many issues remain: what should be the initial configuration of cells, maybe Jean L. Durand's (1802) compendium of neo-classical design rules, which generation to stop at, neighborhood definition, type of rule, definition of cell, shape of spatial unit, overall scale, and support conditions. All of these issues, and others, can be addressed at the beginning of such a generative process. This enables the process to develop the unexpected, as well as, the architecturally possible.

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